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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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DEPARTMENT OF COMMERCE - BUREAU OF MINES

# BLASTING PRACTICES AS THEY AFFECT THE ROOF OF COAL MINES IN OHIO, PENNSYLVANIA, AND WEST VIRGINIA[1]

By J. N. Geyer[2]

## REASON FOR INVESTIGATION

In coal mining it is essential to maintain the roof over working places and roadways in the safest condition possible. To this end every effort should be made to win the coal with the least injury to the immediate roof strata, as broken strata certainly present a greater hazard than a sound roof. The chief causes of injury to the roof in mining are inherent in the method of development and recovery and the blasting practices followed. The first, which may produce severe stresses in the roof, weakening it over comparatively large areas, has been discussed in previous papers[3] and will not be treated here. The second cause is local in effect, but with the same general method of blasting being employed throughout a mine having uniform roof conditions, similar effects on the roof may be expected.

In the Bureau's investigation of accidents caused by falls of roof and coal it has been necessary to make a careful study of blasting practices and their effect on the immediate roof. The purpose of this paper is to show the effect of the observed methods of blasting on different types of roof and to point out methods that have been proved to be least harmful to the roof strata.

The data used in preparing this paper have been compiled from reports made by Bureau engineers engaged in the study of falls of roof and coal, and embrace mines opened in the Pittsburgh coal in Ohio and Pennsylvania and the Pittsburgh and Sewickley coals in West Virginia.

## DESCRIPTION OF COAL BEDS AND ROOF

### Pittsburgh Bed

The Pittsburgh coal bed varies from 52 to 108 inches in thickness in the mines studied. Aside from the variations in thickness, the physical characteristics of the bed as observed in the different mines have a marked similarity. The coal is of bituminous rank, of hard texture, and is characterized by its bright appearance and blocky fractures. Two bone or shale partings are generally present in the bed, the upper one occurring 24 to 48 inches below the roof and the second 3 to 6 inches below the first. These partings are 1/4 to 1 inch thick.

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used; "Reprinted from U.S. Bureau of Mines Information Circular 6738."

2 Associate mining engineer, U.S. Bureau of Mines, Pittsburgh Experiment Station, Pittsburgh, Pa.

3 Geyer, J. N., Factors and Conditions That Aid in Alinement of Pillar Extraction Lines in Coal Mines; Inf. Circ. 6727, Bureau of Mines. In press.
Paul, J. W., and Plein, L. N., Methods of Development and Pillar Extraction in Mining the Pittsburgh Coal Bed in Pennsylvania, West Virginia, and Ohio; Bureau of Mines Information Circular. In press.



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The immediate roof is not as uniform in character as the coal bed, but it has certain members persistent over a large part of the field. Chief of these is the jointed gray clay known as "draw slate" or stone that occurs immediately over the coal. This varies in thickness from little more than 1 inch to over 4 feet and shows wide variations over short distances; the average thickness over the field is approximately 12 inches. The draw slate is hard when first exposed, but it disintegrates rapidly on exposure to the atmosphere and becomes plastic in the presence of water. As the clay is rarely self-supporting and because of its tendency to disintegrate when exposed, timber support is impracticable except as a temporary measure. This necessitates taking the draw slate or else leaving a stratum of head coal below it strong enough to hold the draw slate between timber supports and thick enough to protect it from contact with the mine air.

Overlying the draw slate is a stratum of high-ash coal which in a few places is over 3 feet thick but is generally between 10 and 18 inches and averages about 12.5 inches. The rider coal is not as persistent or as uniform as the draw slate. In some localities it is absent or appears as a carbonaceous shale; in other sections, the coal is multiple bedded, the benches being separated by shale or clay partings, 2 to 5 inches thick. Where the draw slate is taken down, the rider coal generally affords a dependable roof if it is at least 6 inches thick. The members of the immediate roof overlying the rider coal consist of clay and shale of varying strength and thickness. These are often important factors in roof control and support, but they seldom require special consideration in blasting, except as they may be affected by the underlying strata.

### Sewickley Bed

The mines studied operating in the Sewickley coal were in Monongalia County, West Virginia. In these, the coal varied from 45 to 72 inches in thickness. The coal is of bituminous rank, hard texture, and has a blocky fracture. The bed often has a bone or shale parting 1/4 inch to 1-1/2 inches thick near the middle, separating it into two benches.

The immediate roof consists of shales having a maximum thickness of 10 feet but sometimes disappearing entirely, in which case a hard sandstone lies immediately on the coal. The immediate roof shales are generally strong, but in some parts of the field the roof behaves as if it were heavily stressed, causing the strata immediately over the coal to break with little or no warning in headings and rooms. No definite indications were found, however, between the roof behavior and the method of blasting.

## STATE BLASTING REGULATIONS

The blasting practices in any coal bed are regulated to a large extent by the mining laws of the State in which the mines operate. Most of the laws relating to blasting are primarily to prevent blown-out shots; however, these same measures tend to mitigate the violence against the roof. The sections of the bituminous coal mining laws of Pennsylvania, Ohio, and West Virginia relating to blasting practices that may effect the roof follow:

### Pennsylvania Bituminous Mining Laws, 1926

#### Article IV

Section 9. The mine foreman shall direct that the coal is properly mined before it is blasted. "Properly mined" shall mean that the coal shall be undercut, center-cut, top-cut, or sheared by pick or machine, and in any case the



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undercutting shall be as deep as the holes are laid. In mines generating explosive gas in quantities sufficient to be detected by an approved safety lamp, when the coal seam is 5 feet 6 inches or more in thickness, "properly mined" shall mean that in all entries less than 10 feet wide, wherein the coal is undercut, it shall also be sheared on one side as deep as the undercutting before any holes are charged and fired, or the coal shall be blasted in sections by placing the first hole near the center of the coal seam. . . . . .

Section 10. . . . .The mine foreman, or the assistant mine foreman under instructions from the mine foreman, shall direct that the holes for blasting shall be properly placed, and shall designate the angle and depth of holes, which shall not be deeper than the undercutting, center-cutting, top-cutting, or shearing, and the maximum quantity of explosives required for each hole, and the method of charging and tamping. . . . .

Section 14. In such portions of a mine where explosive gas is being generated in quantities sufficient to be detected by an approved safety lamp, and in which locked safety lamps are used, the mine foreman shall employ a sufficient number of competent persons, who are able to speak the English language, to act as shot-firers, whose duty shall be to charge, tamp, and fire all holes properly placed by the miners, and to refuse to charge any holes not properly placed. No holes shall be fired by any person other than a shot-firer. . . . .

In all mines in which coal is blasted from the solid, all holes shall be fired when all the workmen are out of the mine except the shot-firers and other persons delegated by the mine foreman to safeguard property.

Article XI

Section 8. Shot firing by electricity.

89. Shot firers: Only competent persons, who have the necessary training and skill, and who have been properly instructed in the work, and duly authorized by the mine foreman, shall be allowed to fire shots electrically in any mine.

Article XXV
Special Rules. Duties of Miners

Rule One. . . . .It shall be the duty of the miner to mine his coal properly before blasting, and to set sprags under the coal while undermining, to secure it from falling. . . . .

West Virginia Mining Law, 1929

Section 23. In any mine in which solid shooting is done the district mine inspector is authorized to prescribe the condition under which solid shooting may be done; any operator or mine foreman, who causes or permits any solid shooting to be done therein without first having obtained a written permit from the district inspector, or any miner therein who shoots coal from the solid without first having obtained permission so to do from the operator or mine foreman, shall be guilty of a misdemeanor and upon conviction shall be fined as hereinafter provided.

Section 62. . . . .No person shall fire more than one shot at a time, and after firing said shot he shall not return to the working place until the smoke has cleared away; . . .



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Section 63. In no case shall more than one kind of explosive be used in the same drill hole, and every blasting hole shall be tamped, except as is necessary to accomplish cushion blasting, full from the explosive to the mouth, and no coal dust or inflammable material shall be used for tamping. Cushion blasting shall not be allowed in any case unless written permission is granted by the department of mines. Dynamite shall not be used in blasting coal. No fuses shall be used unless permission is granted by the mine foreman and in no case shall fuses be used of less length than the drill hole.

Rules

Use of Explosives

Rule 9. Not more than one shot shall be fired at one time and only one kind of explosive used in the same hole.

Rule 11. Shooting off the solid is prohibited, except by permission in writing from the mine foreman, under conditions prescribed by the District Mine Inspector.

Ohio Mining Law, 1931

Section 110. Squibs and fuses; missed shots. . . .Two or more shots shall not be fired in the same face, unless all fuses used are at least 12 inches different in length, or unless the shots are fired simultaneously by electric caps or electric squibs.

Section 113. Regulation of drill holes. When a miner drills holes in the face of coal for the purpose of blasting and such drill hole bottoms in the permanent roof, he shall not charge or fire such drill hole. In no case shall a miner drill a new drill hole in such a way that any part of it shall be within 12 inches of any part of an unused drill hole. . . . . .

Section 115. Solid shooting prohibited without permit. The owner, lessee or agent of any mine shall not order or permit solid shooting in a mine in this State unless he has obtained written permission to do so from the chief, division of mines, who may issue such permit when in his judgment such solid shooting is necessary for the just and reasonably profitable operation of such mine.

It will be noted that certain provisions are made in each State for blasting coal from the solid. In Ohio, definite provision is made against charging and firing shots in holes drilled into the permanent roof, and in Pennsylvania the angle depth and maximum charge of explosive used in each hole is to be designated by the foreman. In West Virginia, the law stipulates that shots shall be fired singly and that the workmen shall not return to the face until the smoke has cleared away.

Methods Used in Pittsburgh Bed

Mines in the Pittsburgh coal may be divided into two groups - those in which the draw slate is taken down and those in which the draw slate is supported. In the former group the entire coal bed is mined and the draw slate because of its inherent weakness and slaking characteristics when exposed must be taken down. In the latter group the coal bed is thick enough to allow leaving several inches of head coal to protect the draw slate without hinder-



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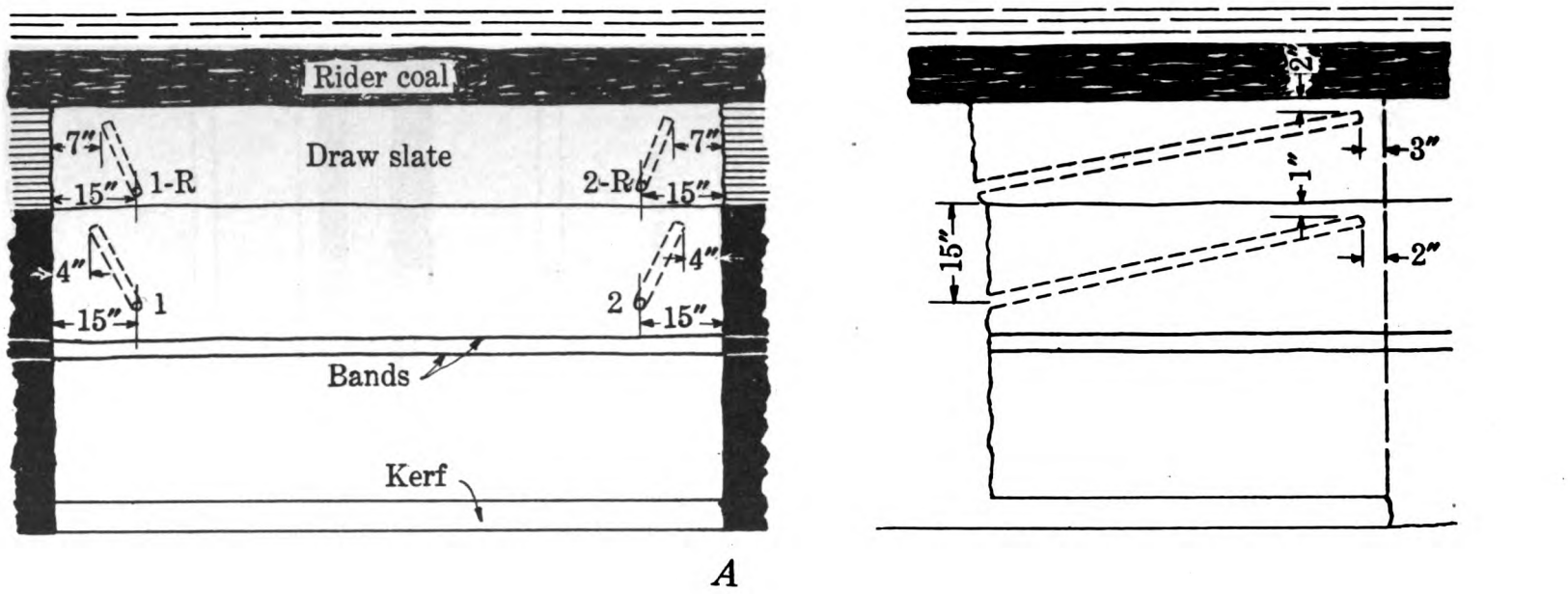


**Figure 1.— Position of drill holes in Pittsburgh coal bed where draw slate is taken down. *A*, Heading face and section; *B*, room face and section.**

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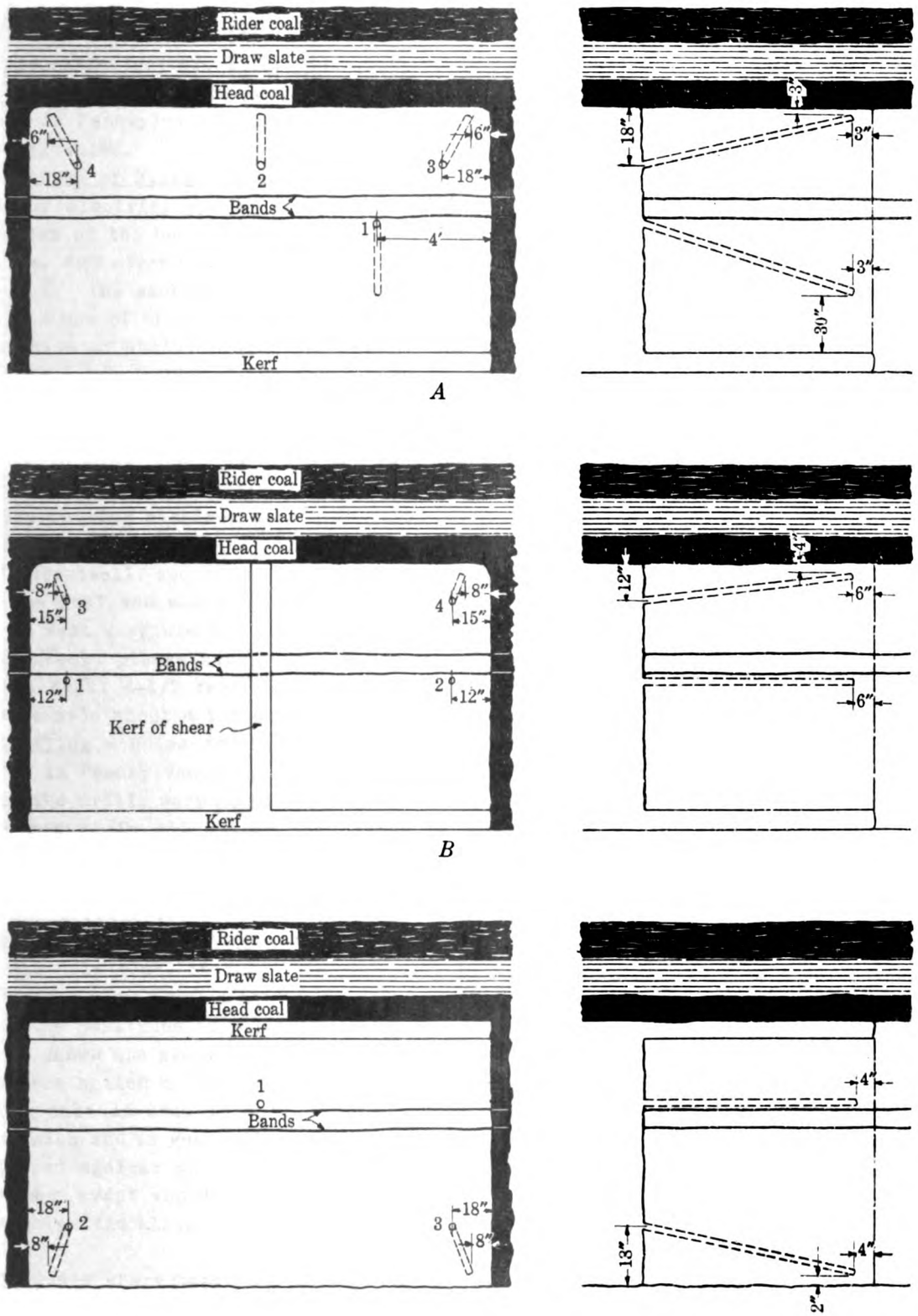


**Figure 2.— Position of drill holes in Pittsburgh coal bed where head coal is left to protect draw slate. *A*, Where coal is undercut and hand loaded; *B*, undercut and center sheared, hand or machine loading; *C*, where coal is top-cut.**

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ing transportation. If this head coal is of good quality, it is then recovered as the pillars are extracted; or, if of poor quality, as is often the case, the coal is not recovered.

In approximately 60 percent of the mines studied in the three States (all in Ohio, 67 percent in Pennsylvania, and 30 percent in West Virginia) the draw slate was taken as the places advanced.

Cutting or Mining.- In Ohio, all coal was cut by shortwall or chain-breast machines driven by electricity, the kerf being 5-1/2 to 6 feet deep and at, or a few inches above, the bottom of the bed. In the Pennsylvania mines, where the draw slate is taken, all rooms, headings, and crosscuts are cut by machines and over 50 percent of the pillar coal is machine cut. The machines were electrically driven and of the shortwall type except in four mines, in one of which a turret-type machine that remained on the track was used and in the other three of which combination cutting and shearing machines were used. The kerf was on or within a few inches of the floor in each case. In the three mines, where machines equipped for shearing were used, the coal was center sheared to the back of the undercut. This was done in each case to facilitate blasting for machine loading. The only mines in West Virginia in which the draw slate was taken were in the Panhandle district. In these all of the coal was bottom cut with shortwall-type electric machines.

Top-cutting machines were used in 30 percent of the mines in which head coal was left to protect the draw slate. In the other mines the coal was cut on the bottom with chain-breast, shortwall, and track-mounted machines, with the exception of two mines in Pennsylvania where the coal was mined by pick. The coal in two Pennsylvania mines and in parts of two mines in West Virginia was center-sheared to the depth of the undercut. The depth of kerf in machine-cut places varied from 5-1/2 to 8 feet and, where the coal was hand mined, the kerf was about 4-1/2 feet deep. In the mines where pick mining was used exclusively, the cuts were made about 4 inches below the draw slate.

Drilling.- Holes for blasting were drilled with power drills in one mine studied in Ohio, 11 in Pennsylvania, and in 5 mines and part of another in West Virginia. In most instances the drills were mounted on the cutting machines. Compressed air operated the drills in two mines; in all others the drills were driven by electricity. Breast augers were generally used by the miners for hand drilling.

Headings are driven 8 to 10 feet wide in the mines where the draw slate is taken, and 2 holes are drilled for blasting the coal. If the draw slate does not fall with the coal or is too firm to be barred down, 1 or 2 holes are drilled in the rock to blast it down. Rooms where the draw slate is taken are generally 18 to 24 feet wide and 2 to 4 holes are drilled in the coal; 1 to 3 holes are drilled in the draw slate if it cannot be barred down. Figure 1 shows the positions of holes in headings and rooms where the draw slate is taken. The dimensions shown are averages for the district. The holes drilled in the draw slate are started near the bottom of the stratum and not at a fixed distance from the roof. Hole 1 or the snubbing shot is used in only a few mines; it is placed at any point between the rib and center holes and is generally just below the bands. The top holes in nearly all of the mines are stopped against or within 2 inches of the draw slate. This sometimes shatters the rock and in any event would tend to weaken it. In a few mines the holes were stopped 4 to 6 inches below the slate. This practice brought the coal down effectively without disturbing the roof.

In mines where head coal is left to protect the draw slate the headings are driven 10 to 12 feet wide, the usual width being 12 feet. Rooms in these mines are 10 to 16 feet wide, 12 and 14 feet being common widths. Where the coal is undercut and blasted for hand loading, 2 to 4 holes are drilled; the general positions for these holes are shown in figure 2,A. Holes corresponding to 3 and 4 are always drilled; these are started 6 to 30 inches from the ribs and 8 to 36 inches from the head coal. They terminate 1 to 12 inches from the ribs,



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not more than 6 inches from the head coal and within 6 inches of the back of the kerf. Hole 2 is seldom used unless the coal does not break away from the head coal readily; it is generally parallel to the line of sights and has the same pitch and depth as the rib holes. Hole 1 is drilled in several mines; it is generally started below the bands but in a few instances is just above or between them and may be at any point between the rib and the center of the place. The hole may be drilled flat or may dip toward the back and should terminate within 6 inches of the back of the cut.

Figure 2,B, shows the general position of holes where the coal is undercut and center-sheared. As in figure 2,A, holes 3 and 4 are always drilled but holes 1 and 2 are not generally used except with mechanical loading. The latter holes are drilled flat and parallel to the line of sights. In some mines where mechanical loading is used it has been found that shearing produces lumps too large to be handled by the loading machine conveyor without jambing against the roof. In one of these mines this was overcome by drilling 6 holes and not shearing. The 2 additional holes were drilled in the middle, one in line with the roof holes and one below the bands. The 3 holes below the bands were then drilled parallel with the line of sights, but dipped so that the back was only 18 inches above the kerf. This causes the coal blasted down by these shots to be thrown forward, thus making more room for the coal brought down by the top shots.

Top-cutting machines were used in several mines, principally when the head coal was left up. About half of these mines used 3 holes, while in the others only 2 were drilled. Figure 2,C, shows the common practice for drilling in top-cut places. Holes 2 and 3 have the general positions shown in all of the mines. The top hole when used is always in the center with respect to the ribs and is drilled parallel to the line of sights. In most instances it is started at the bands and is parallel to the bedding planes as shown; however, in one mine this hole is started 36 inches above the floor and is pitched to be approximately 14 inches from the kerf at the back; the hole is stopped 6 inches from the back of the cut. This position is used because the shots are all fired before the loaders enter the mine, and by drilling the hole in this position the coal loosened by the shot is thrown from the face, allowing greater freedom for the bottom shots.

Explosives.- Permissible explosive and black blasting powder in pellet and granular forms were used in the coal and in the draw slate where it was blasted. Permissible types of explosive were used in most of the mines, including those listed as nongassy. The quantity of permissible explosive used in each drill hole varied from 1 to 5 cartridges and of pellet powder from 1/2 to 3 cartridges. The coal produced per pound of explosive ranged between 4.3 and 18.1 tons for permissible explosive and 4.5 to 15.8 tons for black blasting powder in both forms. Shot firers were employed in 60 percent of the mines, and in a few mines either all or a part of the shooting was done on the preparation shift before the loaders entered the mine. In the other mines all shots were fired by the loaders, using squibs for black powder and electric detonators for the permissible explosive.

Effect on the Roof.- Where the draw slate was taken, more carelessness was noted in placing the top holes and in the quantity of explosive used than in the mines where head coal was left. In some cases the loaders placed the back of the top holes against the roof purposely to break the draw slate without blasting in it. This sometimes produced the desired result, but more often the blast was not sufficient to bring the slate down, yet would loosen it enough to make its support while loading the coal difficult and extremely hazardous. Observations in a large number of mines have shown that the explosive need not be less than 4 inches from the roof to break the coal from the draw slate and that at this distance there is little danger of injuring the roof.

In mines leaving head coal to protect the draw slate, more care is generally exercised in drilling and charging the holes to prevent shattering the head coal. However, in a few



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mines the head coal was repeatedly shattered or cut along the ribs by the force of the explosive. This was particularly noticeable in one mine where the holes were drilled with power drills, swivel-mounted, on top of the mining machines, the latter remaining on the track while cutting and drilling. No provision was made for lateral movement of the drills, nor could they be raised or lowered except by tilting the drill; consequently, all holes radiated from a common point and were frequently drilled too high into the head coal or extended too far into the ribs. With the exception of this mine, the head coal appeared to be less broken in mines where the holes were drilled by special crews using power drills than where this work was performed by the loaders.

### Methods Used in Sewickley Bed

Head coal was left to support the immediate roof in only one of the mines studied in the Sewickley bed; in all others the coal was taken to the immediate roof. Headings and crosscuts are driven 12 to 14 feet wide and rooms are 14 to 20 feet wide, the average being 18 feet.

The coal was undercut on the floor with electric shortwall machines in all but one mine where the coal was hand mined. The coal is cut to a depth of about 6 feet with machines and about 4-1/2 feet when hand mined.

The general practice in the district is to drill two holes for blasting in headings and rooms. All holes are drilled by the miners, using breast augers. The positions of drill holes shown in figure 3 are typical for all mines except the one leaving head coal. In this mine the holes are started about 24 inches below the roof and pitched so that the hole terminates over the back of the kerf about 12 inches below the roof. The coal then breaks when blasted about 6 inches above the hole, leaving 6 inches of firm coal against the roof.

The coal was blasted with permissible explosives in nearly 60 percent of the mines and black blasting powder in either pellet or granular form in the other mines; the loaders fired all shots at any time during the working shift. The coal produced per pound of permissible explosive ranged between 7.9 and 11.8 tons and with black powder 7.3 and 10.0 tons. The permissible explosive was detonated electrically, current being taken from small nonpermissible dry cell batteries, and the black powder, in both forms, was fired with squibs.

In the Sewickley bed no definite proof of blasting's having seriously affected the roof was found. In some instances, however, where the roof was jointed or heavily stressed, blasting may have opened the joints or weakened the roof, causing larger falls than otherwise would have occurred.

## METHOD OF PROTECTING THE ROOF

In general, three factors, separately or in combination, affect the safety of the roof in blasting: The position of the kerf; the position of the drill holes; and the characteristics and quantity of explosive used. These may be manipulated separately or in combination to produce the desired results. Changing the position of the kerf from the bottom to the top or some intermediate point might afford the greatest protection to the roof, but in many instances this would entail considerable expense to the company in replacing the machines in use with a type designed for top cutting; so it is often advisable to consider the less expensive methods first.

### Choosing the Correct Explosive

It is now possible to obtain a permissible explosive that meets any reasonable condition encountered in coal mining, provided that the explosive is handled in the manner recommended



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by the manufacturer. Choosing the most satisfactory explosive may require considerable experimental work by an engineer who is experienced in handling explosives and has a working knowledge of the types of permissibles on the market. Most manufacturers of explosives have engineers who will study conditions in a mine and recommend the explosive manufactured by their company that will give the best results. The final choice should be the explosive that leaves the coal in the most marketable form with the least possible injury to the roof.

## Position of Drill Holes

A factor of as great and sometimes greater importance to the roof than the explosive is the position of the drill holes, because the most satisfactory explosive obtainable will fail of its purpose if fired in a hole improperly placed. Some of the more common errors observed in the mines studied are:

(1) Drilling holes too deep for the depth of cut;
(2) Directing the holes toward the ribs;
(3) Inclining the holes at too great an angle toward the roof;
(4) Holes too close to the roof;
(5) Drilling the holes before the place has been cut.

The first three of these errors result in or may produce effects comparable to blasting off the solid. This shatters the coal, producing an excessive amount of slack which is often a drug on the market, and shatters or loosens the roof strata, causing needless expenditure in cleaning falls or setting additional supports to make the weakened roof safe. A frequent cause of drilling the holes too deep is that the miner assumes that the place has been cut to the full depth of the cutter bar and he then drills the holes to the full depth that the machine would be able to cut; consequently, if a cutter bar were 6 feet long, and, due to irregularities on the face, had cut only 5 feet deep, the hole would be 1 foot in solid coal; and, if three cartridges 8 inches long were charged in the hole, one half of the charge would be in solid coal. This may easily be prevented if the miner will measure the depth of the cut at the point where the hole is to be drilled. The hole should then be stopped 4 to 6 inches short of the depth of the kerf.

Directing the hole toward the rib, or gripping the rib, is common practice among miners. This is probably due to the fact that machinemen frequently cut a fan-shaped kerf whose rib lines the miners are inclined to follow in drilling. Either gripping the ribs or pitching the holes at too great an angle with the roof will produce effects similar to blasting off the solid, as illustrated in figure 4, in which the shaded portions show the coal subject to the greatest shattering effect. It will be noted that practically the entire force acting perpendicular to the drill hole may be directed against solid coal, which confines the gases and causes excessive shock to the coal and roof. Both of these practices may be corrected easily by the supervisory staff in the mine and should effect a saving to the miner in explosives, produce less fine coal, and reduce the cost of maintaining the roof. Rib holes should be drilled parallel to the line of sights, even if the cutting machine has gripped the ribs. The distance from the rib at which the holes should be drilled depends on the character of the coal, thickness of the bed and width of the places, but they should be drilled at the maximum distance at which the shots will trim the ribs. In the Pittsburgh coal bed the distance ranged between 6 and 30 inches, but tests conducted by the Bureau of Mines indicate that 12 inches will generally give best results. All top holes should be drilled as nearly flat as possible and in the Pittsburgh bed the back of the hole should be at least 4 inches from the roof. Where the miner uses a breast auger in high coal, a bench should be provided for him to stand on while drilling so that the hole may be kept level instead of slanting upward. The holes should be stopped approximately 6 inches short of the kerf and in no event should holes be drilled deeper than the kerf.



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Drilling holes before the place has been cut is a practice sometimes encountered. This practice is most common in mines where the loader is required to wait on cars or where the cutting is done while the loader is in the mine. In either instance the loader, wishing to waste no time, will drill holes for the next cut as soon as he has removed the loose coal from the face. Holes so drilled may be deeper than the cut or may penetrate into the rib beyond the cut; in either case the shot will be fired in solid coal.

## Position of the Kerf

In some mines having an exceptionally tender roof, little improvement can be effected by changing the explosive or the position of the drill holes. Under such conditions it is generally advisable, and sometimes imperative, that top-cutting machines be used; or, if the nature of the bed makes top cutting impracticable, the cut may be made at a point near the top, and the coal above the kerf may then be barred down or blasted with light charges of explosive. A roof study was made in one mine opened in the Pittsburgh bed where it would have been economically impossible to have operated the mine without top cutting. Overlying the coal in this mine was a calcareous clayey shale interspersed with lenticular masses of limestone which could not be held when exposed. To protect this roof, the coal was top cut 6 to 12 inches below the roof and the coal above the kerf was not recovered. In another mine, room pillars that had been standing for several years were being recovered by pick work because of the weakened roof. The miners cut a kerf 8 to 12 inches below the draw slate and it was noted that the head coal in these pillar places was stronger than the head coal in advance places which were cut on the floor with shortwall machines. In the latter places the explosive had not shattered the head coal, but when tested it emitted a drummy sound, and the vibrations set up indicated that the coal had been loosened along the cleats and bedding planes.

## Supervisory and Disciplinary Measures

Little can be accomplished toward protecting the roof without close supervision and rigid discipline. Tonnage men naturally wish to produce the greatest amount of coal possible with the least effort. The machinemen, therefore, try to cut as much coal as possible, and the loaders desire to blast the coal in a manner that will reduce pick work to the minimum. As a result, unless closely supervised and disciplined, the machinemen will cut the working places too wide and the loaders will overcharge the holes, thus shattering the coal and injuring the roof. One of the first duties of an operating company is to draw up a code of rules and standards for the guidance of the officials and employees. Those relating to blasting should embody the best practices for the production of marketable coal with the least damage to the roof and should set forth clearly all operations that may be standardized, including the manner in which the loader should prepare the face for cutting, instructions for the machinemen, position of drill holes and manner in which holes are to be charged and fired. The officials should then supervise the work closely and tolerate no violations of the rules or standards. It is often difficult for a section foreman to give each phase of the work on his section the time it requires. Where shot firers are employed they have authority to refuse to fire any shots in places where the company rules or State mining laws are violated. If competent shot firers are employed, this method provides closer supervision than can be had when loaders fire the shots, and precludes the possibility of shots' being fired in violation of the rules. A most commendable policy of some companies is to employ as shot firers only men who are certified first-grade mine foremen.



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Where shot firers are not employed, the damage caused by improper blasting is often done before it comes to the attention of the officials. The method of disciplining those having violated the rules is generally a reprimand for the first offense, a lay-off for the second, and dismissal for the third. This policy, however, works an unnecessary hardship on the company; for the first offense, it must bear the cost of timbering the place if cut too wide or if the roof has been broken; and, for the second offense, it loses the productive efforts of the violator in addition to the expense of making the place safe. One company has overcome a part of these difficulties by requiring the violator of the rules to make the place safe on his own time as punishment for the first and second offenses, and, after the third, he is dismissed. This rule applies to both machinemen and loaders, depending on whom the responsibility for the violation rests in the opinion of the official.

Because of the greater centralization of responsibility, the use of power drills operated by regular drill crews will result generally in a more uniform placement of holes than can be accomplished when the drilling is done by the individual miner.

## ADVANTAGES GAINED BY IMPROVED BLASTING PRACTICES

The benefits to be derived from improving the cutting, drilling, and blasting practices include increased safety to those underground and economy to the miner and operator. The more important advantages, stated briefly, are:

(1) Protection to the roof;
(2) Increased marketability of the coal;
(3) Economy in handling waste material at the face;
(4) Facilitated separation of impurities from the coal.

Protecting the roof from all unnecessary shock often prevents joints from being opened which will destroy any keying effect in the strata that might otherwise have held or assisted in holding the roof. Open joints also provide a passageway for air and moisture which cause the disintegration of many strata that occur over coal beds. A roof so weakened must then be securely supported or the loose material taken down and the overlying strata frequently supported, thus increasing the cost of the coal. Such a roof creates a serious hazard to those working under it, especially haulagemen, who may be injured by falls caused by derailed cars striking timbers carrying loose rock. The compensation costs of such accidents have not been segregated at the mines studied, but it is an item of cost that should be given careful consideration. In passing, it is suggested that if all coal companies would keep as detailed a description of the cause or causes of each accident as are kept of the nature and extent of the injury, they would find it less difficult to formulate constructive measures for the reduction of accidents.

Practically any blasting practice adopted for the purpose of protecting the roof should increase the marketability of the coal by reducing the quantity of slack made. Some companies report no reduction where the coal is cut horizontally and sheared, but this they attribute to the increase in machine cuttings and not to greater degradation as a result of the explosive. In top cutting no reduction in fine coal will be effected unless the drill holes are placed to reduce shattering of the coal as described for top holes; however, if the holes are drilled flat or nearly so and parallel to the line of sights, the reduction in fine coal should be similar to that in undercut places.

Blasting the coal with a minimum of degradation will generally result in a cleaner product at the face, especially if the impurities occur as bands which are readily shattered. When the refuse is badly shattered, it may escape the notice of the loader or he may not take time to remove all the small pieces, whereas large pieces could seldom fail to attract his attention. Removing the refuse at the face would reduce the amount of cleaning neces-



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sary at the tipple and obviate payment for refuse at the price of coal. Some companies have saved the cost of elaborate cleaning plants by cutting out a parting or making the cut immediately above or below the band and removing the impurity before blasting. The practicability of this should be carefully considered because large saving may possibly be made in this manner.

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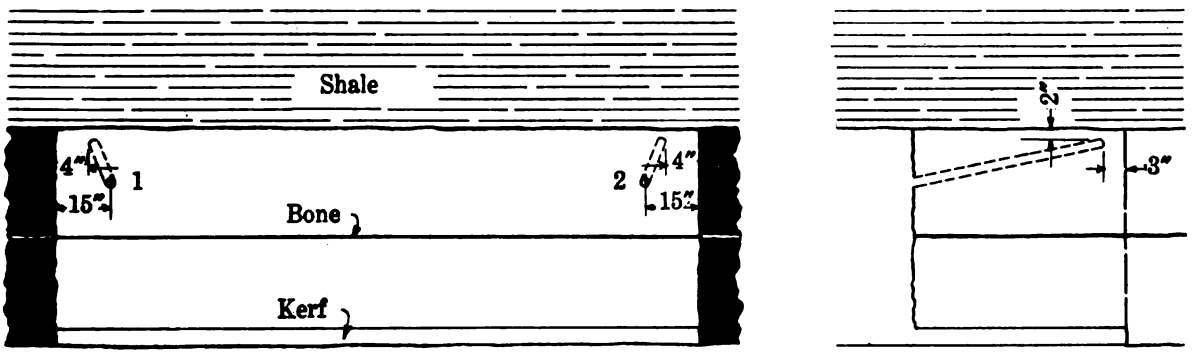


Figure 3.—Position of drill holes in Sewickley coal, West Virginia.

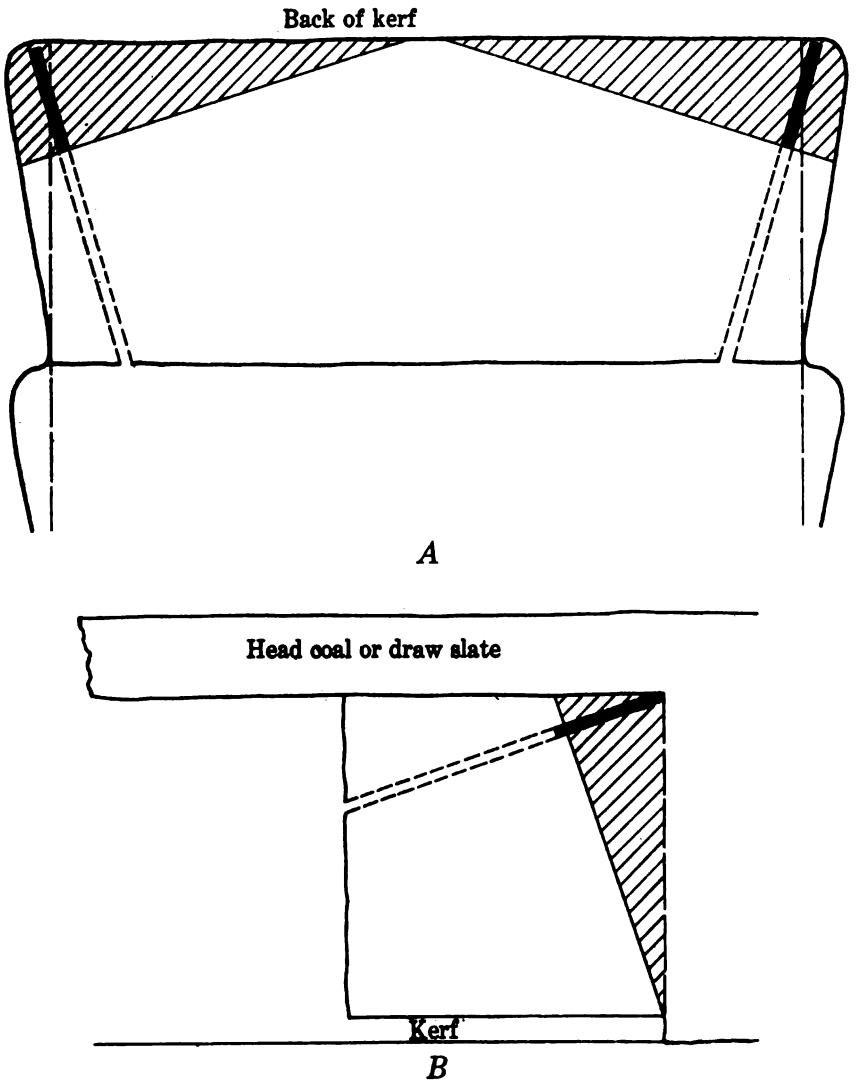


Figure 4.—Areas in which explosive acts against solid coal when the holes grip the ribs and are at an angle with the roof. *A*, Plan; *B*, side elevation.

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